RESEARCH
PUBLICATION
NO. 17

EVALUATION OF THE HIGH RATE - COMBINED TANK ACTIVATED SLUDGE PROCESS

THE ONTARIO WATER RESOURCES COMMISSION

RESEARCH PUBLICATION #17 - HIGH-RATE COMBINED TANK ACTIVATED SLUDGE PROCESS

There have been queries concerning the tables of operational data as presented in the appendix of this report. The tables present the highest, lowest and average values of BOD, SS and percent reduction of collected data. The maximum BOD values of the raw sewage and of the effluent do not necessarily occur concurrently and thus the percent reduction presented has not been prepared from the preceding columns but is the greatest reduction obtained from the sets of data. The figures presented in the tables are independent of each other.

i.e. Referring to the table of Page 35, from the data collected the strongest raw sewage BOD value was 133 ppm, the poorest effluent BOD value was 18 ppm and the best BOD percent reduction obtained from any set of raw-effluent samples was 96%. Similarily, the weakest raw sewage SS value was 12 ppm, the lowest effluent SS value was 1 ppm and the poorest SS percent reduction obtained from any set of raw-effluent samples was 63%.

EVALUATION OF THE
HIGH RATE - COMBINED TANK
ACTIVATED SLUDGE PROCESS

By:

S. A. Black, P. Eng.

Division of Research
Publication No. 17

A. J. Harris
Director

Dr. J. A. Vance
Chairman

D. S. Caverly
General Manager

The Ontario Water Resources Commission

- NOTICE -

This report is made in good faith and from information believed to be correct, but without any warranty, representation, endorsement, approval or guarantee of any kind whatsoever, whether express or implied, with respect thereto, and in particular, the Commission disclaims any responsibility for the accuracy, completeness or usefulness of the report and does not represent or warrant that the use of the information contained in the report will conform to the law or may not infringe any rights under the law.

The Commission and its employees and agents shall not be liable in any manner whatsoever in respect of the the information contained in the report, and any use of such information shall be at the risk of the user.

SUMMARY

The report presented herewith is an evaluation of a modification of the activated sludge process which employs a combined aeration and settling tank unit. Very high rates of sludge return are characteristic of this process as well as shorter detention times than those employed by the conventional activated sludge process.

Information for this report was obtained from published material and through an inspection tour of existing installations within the Province of Quebec.

The following conclusions are presented as a result of this process evaluation:

1. The High Rate - Combined Tank activated sludge process as studied in this report is a simple secondary treatment process capable of a high degree of treatment, comparable to that of the conventional activated sludge process.

2. The High Rate - Combined Tank process of sewage treatment is capable of operating efficiently over a wide range of operating conditions.

3. Plant operating costs are somewhat less than those of the conventional activated sludge process, particularly in relation to operator wages. These plants are operated with considerable less supervision than is required for the conventional process.

4. Plant capital costs are less than those of the conventional activated sludge process and are competitive with those of aerated lagoons and large waste stabilization pond installations while producing a consistently better effluent.

5. The design criteria adopted by the Quebec Water Board appear to produce a satisfactory effluent under a wide range of operating conditions.

ACKNOWLEDGMENTS

The assistance of the Quebec Water Board, of Delaney, Belschner and Associates, Consulting Engineers and personnel of Societe Generale D'Epuration et D'Assainissement Ltee., Degremont and Infilco in providing operating and design data is gratefully acknowledged.

Appreciation is hereby given to all others who assisted in the collection of data for this report.

TABLE OF CONTENTS

TABLE OF CONTENTS - CONT'D

Page No.

LIST OF TABLES

LIST OF FIGURES

1.0 INTRODUCTION

With a continued interest in new developments in sewage treatment processes, the Ontario Water Resources Commission authorized the evaluation of a modification of the activated sludge process for application in the treatment of municipal wastewaters. The proprietary treatment units investigated in this study employ combined aeration and settling tank units having high loading factors and high rates of sludge return.

The report presented herewith is based on information obtained from published material and from an inspection tour of existing installations within the Province of Quebec. The inspection tour included observations of plant operation and an evaluation of existing operational records, a discussion of the operational and maintenance problems with local authorities in charge of plants, and conversations with consulting and company engineers.

1.1 The Conventional Activated Sludge Process

The most popular form of secondary sewage treatment in Ontario at present is the "Conventional Activated Sludge" process. The flow diagram of a complete secondary sewage treatment plant utilizing this process appears in Figure 1.

In the conventional activated sludge process overflow from the primary settling tank passes on to the aeration tank where it mixes with active biological solids to form the mixed liquor. The mixed liquor is displaced into the final settling tank where the suspended solids settle out and are returned to the aeration chamber to resume biological action on pollutional materials contained in the primary waste flow. The clarified liquid that is separated from the active solids in the final settling unit overflows as the process effluent. Excess activated sludge is usually wasted to the primary settling tank.

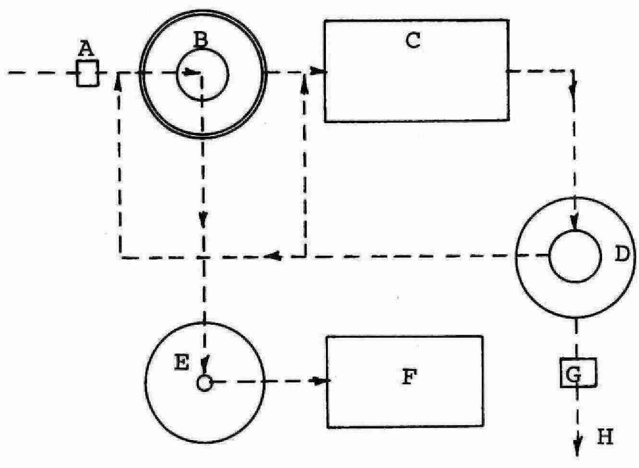


Figure 1 - CONVENTIONAL ACTIVATED SLUDGE PROCESS

A. Screen and grit removal. B. Primary settling tank; Volume: 1½ hr at maximum flow. C. Aeration tanks; Volume: 5-8 hr at design flow + 25% return; air flow: 700:1000 cu ft/lb of BOD. D. Secondary Settling tank; Volume: 2½ hrs at average flow. E. Digester; capacity 32 cu ft/lb of BOD per day. F. Drying beds. G. Chlorine contact chamber. H. Discharge to river.

For domestic wastes with normal per capita water consumption rates (100 gal/capita/day), design values are usually such as to provide aeration detention capacity of 5 to 8 hours, based on the average sewage flow plus 25 per cent return and final sedimentation capacity based on a surface overflow rate of 800 gal/sq ft/day, with a retention period of 2½ hours. Aeration tank loadings vary from 0.2 to 0.5 lb BOD/day/lb MLVSS and 20 to 50 lb BOD/1,000 cu ft/day.

1.2 Modified Activated Sludge Treatment Processes

During the past few years a number of modifications to the activated sludge process have been developed. Their objectives have been to speed up the biological reactions involved and thereby reduce time, space, size and cost to provide varying degrees of treatment. Impetus has been given to this research by the ever rising cost of construction of new sewage treatment works and the keener competition for the public works dollar.

The first real modification, the Step Aeration process, was developed by Gould (1) and provided complete treatment with reduced aeration tank capacity. It was initially used in the Tallmans Island Plant in New York City in 1939.

In 1943 Setter (2) outlined the development of the Modified Aeration process providing for a degree of treatment midway between full treatment and that obtained from plain sedimentation.

In more recent years there has been an increasing trend in the development of higher rate or higher tank loading processes with both complete and partial treatment. Development has taken place most prominently in Germany, Sweden and France. Applications in the United States are Step Aeration, Kraus Process, Biosorption and Contact Stabilization, representing complete or nearly complete treatment; plus Activated Aeration, Modified Aeration and Supra-Activation, as processes providing for intermediate treatment.

With the availability of these modifications it is now theoretically possible to obtain any degree of treatment ranging from that provided by primary sedimentation alone, to treatment of 90% efficiency or higher. The degree of treatment which can be expected from the various processes mentioned above is shown in Table 1. A brief description of each process may be found in a paper prepared by Stewart (3).

1.3 High Rate - Combined Tank Modification

The development of the High Rate - Combined Tank activated sludge process resulted from studies of the fundamental requirements of the activated sludge process to provide for high aeration capacity, introduction of sewage flow, transfer of mixed liquor, rapid sludge return and final tank requirements to obtain a high capacity, complete mixing system.

It can be generalized that the efficiency of biochemical treatment, as measured by BOD removal, is related directly to the weight of biologically active solids in the system and inversely to the applied BOD. It follows that, between limits, neither the wastes concentration nor the mixed liquor aeration period are of fundamental significance. When successful operation at high mixed liquor suspended solids concentrations is possible, considerably smaller aeration basins can be used than have been utilized in the past. Economic and technical limitations in this regard include the oxygenation capacity of the aeration system, the influence of MLSS concentration on the effectiveness of liquid-solids separation and the return sludge capacity required for operation at high MLSS levels.

In conventional plants, with separate sludge activating and secondary settling tanks, the recirculation rate is usually low and ranges from 25 to 50% of the treated flow. If the flow of sewage treated, or the daily quantity of BOD eliminated, is to be increased without changing the tank volume, the weight of sludge in the plant will have to be raised at the same time. The natural course is to attempt

Table 1

DESIGN PRACTICE OF

HIGH-RATE PROCESSES

Process	Degree of Treatment (% BOD Removal)	Primary Reqd.	BOD DESIGN LOAD lbs/1,000 cu ft Aeration Tank	BOD DESIGN LOAD lbs/lb MLSS	Cu ft air/lb BOD Removed
Conventional Activated Sludge	95+	Yes	35	0.33	1,000 - 700
Step Aeration	92+	Yes	50 - 150*	0.33	700 - 500
Combined Tank	90+	Optional	125 - 180	0.66 - 0.97	500 - 700
Kraus	89	Yes	10	0.5 - 0.7	800
Contact Stabilization	85 - 90	Optional	70	0.25 - 0.50	750
Activated Aeration	80 - 85	Yes	50+	-	-
Modified Aeration	60 - 75	No	100	3.3 - 5.0	600 - 400
Supra-Activation	55 - 65	No	400	3.3 - 5.0	400 - 350

* European Practice

Table is taken from Stewart (3)

to increase the recirculation flow. It is very difficult, however, to go beyond a certain level without overloading the secondary settling tanks and increasing the quantity of suspended matter in the treated effluent.

It would also be possible to increase the concentration of solids in the returned sludge by extending the time spent in the secondary settling tanks, but as the sludge there is not aerated it quickly begins to putrefy, with consequent problems.

"Combined tanks" are able to fulfill the above requirements by maintaining sludge in aerobic conditions throughout the purification process and allowing recirculation rates in the order of 400 to 600% of treated flow.

The completely mixed system, embodied in the combined tank system, provides ideal conditions of purification since the organisms are kept in a constant and uniform state of growth. Incoming wastes are completely mixed with the entire contents of the aeration tank. The aeration tank acts as an equalizer of the biological load, and the activated sludge is not so greatly affected by shock loadings. The organisms which are dying are continually releasing nutrient materials, and in such a homogeneously mixed system, this release of and demand for nutrients occur at the same point.

In combined tanks, the sedimentation and aeration zones are closely associated so that the time spent by the sludge in the non-aerated zone is at a minimum. Sludge is not allowed to collect on the bottom of the tank, thus heavy local consumption of oxygen is avoided. The activated sludge is kept continuously in a medium containing dissolved oxygen with the result that much greater loads can be handled than with conventional types of plant.

The High Rate - Combined Tank modification then, is a high load, short term, accelerated sludge return process, with loading factors in the range of 0.5 to 1.0 lb BOD/day/ lb MLVSS and volumetric organic loading values in the order of 125 to 200 lb BOD/day/1,000 cu ft of aeration tank capacity.

Table 1 indicates that the use of primary settling facilities is optional in the operation of the High Rate - Combined Tank process. However, it is recommended that pretreatment facilities for grit removal and comminution be provided.

Because primary sedimentation is not a prerequisite to good plant operation its addition at a later date may be used to increase the allowable organic loading of the entire system, provided the initial plant is hydraulically designed for this increase.

If primary sedimentation facilities are excluded from initial design, scum removal facilities may be required in the settling section of the combined tank unit. Although no scum accumulations were observed on the plants visited in Quebec, scum deposits could occur under specific circumstances, thus greatly deteriorating the quality of effluent.

1.4 Proprietaries of the High Rate - Combined Tank Activated Sludge Process

With most new processes, certain methods and structural modifications are patentable. Such is the case with the High Rate - Combined Tank process. Among those companies with patents applicable to this process are the Societe Generale D'Epuration et D'Assainessement (SGEA), Degremont and Infilco. Chicago Pump holds proprietary rights to the Rapid Bloc process in the United States.

2.0 HIGH RATE - COMBINED TANK PROPRIETARIES

2.1 Rapid Bloc Process

The Rapid Bloc System of sewage treatment was developed in France and is being extensively used in that country under the patents of Mr. Raymond Dufournet with patent applications in Canada, the USA and other countries. This system is illustrated in Figure 2, while Figures 3, 4 and 5 give detailed views of various aspects of the process plant.

As can be observed, the Rapid Bloc System consists of an aeration tank with a final tank adjacent to it to provide for rapid return of the activated sludge to the aeration tank throughout its entire length in contrast to the method employed in the conventional activated sludge plant of returning sludge to the inlet end of the aeration tank. The introduction of return sludge in this manner greatly reduces the time in which the sludge is returned and hence provides a fresher sludge for reintroduction into the aeration tank. Aeration mixed liquor suspended solids have been determined to require, on the average, less than 10 minutes to pass through the settling tank and be recycled to the aeration section. In this system sludge scrapers in the final tank are eliminated.

2.1.1 Design Description

(a) Aeration

The controlling variables in the aeration section of the Rapid Bloc System are the suspended solids concentration in the mixed liquor and the oxygen provided to the mixed liquor. The solids in the mixed liquor may be adjusted in plant operation to accommodate an increase in BOD loading.

Air is introduced in the form of fine bubbles through a dome type porous diffuser at a point adjacent to the opening of the sludge return chimney to the aeration section. (See Figures 2 and 3). Positioning of the diffusers is important

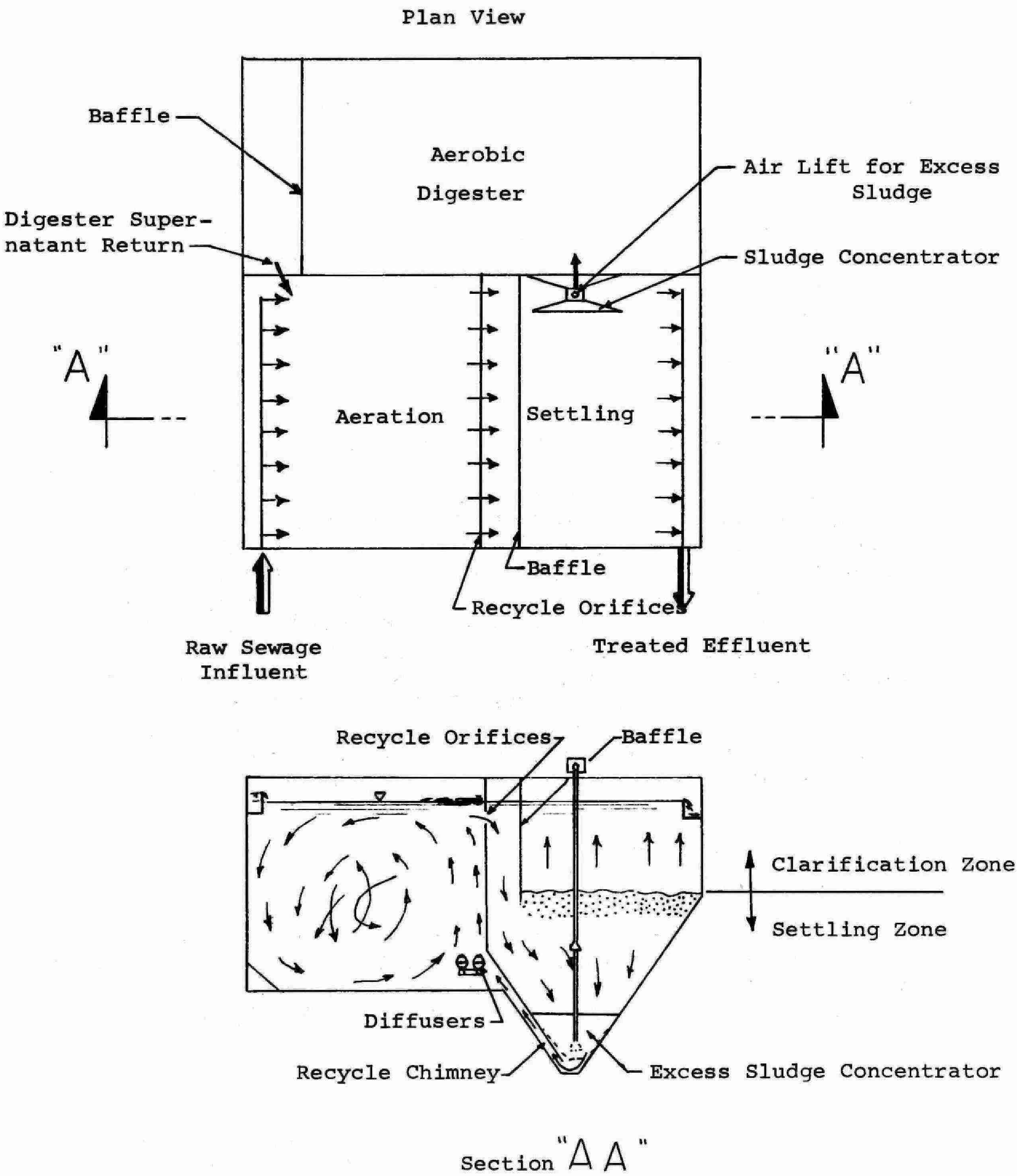


Figure 2 - RAPID BLOC PROCESS

Figure 3 - RAPID BLOC AERATION UNIT

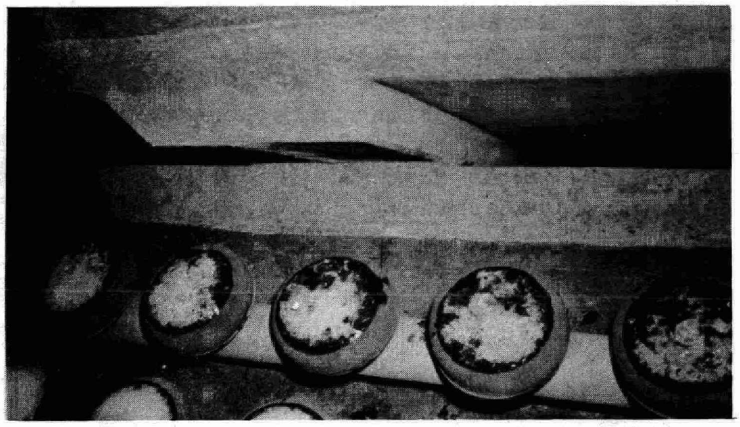


Figure 4 - RAPID BLOC SLUDGE RETURN CHIMNEYS AND DIFFUSERS

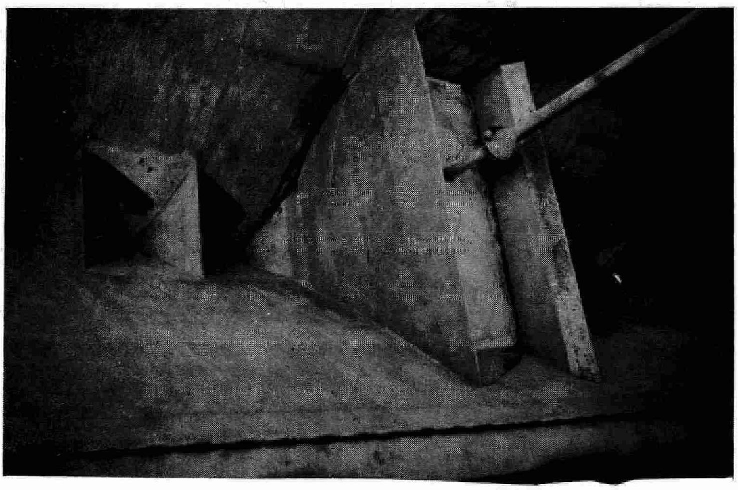


Figure 5 - RAPID BLOC SLUDGE CONCENTRATOR BIN

in developing complete circular mixing and uniform aeration and also in controlling the rate of sludge return. Oxygen transfer is claimed by the manufacturer to have an efficiency of 10% in sewage but this efficiency drops at a rate of about 1% per year until they are cleaned, normally every five to seven years. The cleaning period, however, is largely dependent upon the cleanliness of the air supply.

(b) Settling

Mixed liquor enters the settling section through orifices in the aeration wall and is immediately deflected to a pre-determined zone (5 ft below the surface) by a baffle. This is generally at a point below the surface of the sludge layer which provides a filter for the rising supernatant. Also, at this point there is a downward pull due to hydraulic effects of sludge return which greatly enhances settling. In fact, the improved settling effected through heavier sludge densities and the hydraulic effects decreases the required settling time to 50% of that required by the conventional activated sludge process.

The size of the settling tank limits the design of each Rapid Bloc unit since minimum settling slopes of 53^{o} are required to prevent a build-up of solids.

(c) Sludge Return

Sludge return from the settling section to the aeration section is effected through sludge return chimneys located in the adjoining wall as indicated in the accompanying figures. The design of these return chimneys is critical in the operation of the Rapid Bloc process.

Differences in liquid density between the aeration (air & liquid) and settling sections (liquid only) and differences in liquid level, in addition to location of diffusers provide for extremely high recirculation ratios. Recirculation ratios in the order of 400 to 600% of raw sewage flows are achieved. The return chimney is so constructed as

to maintain a flow-through velocity of about 2 ft per second at design flow. This high velocity should prevent any sludge build-up on the bottom of the settling basin and on the walls of the chimney.

To complete the recirculation cycle, mixed liquor from the aeration section is directed through adjustable ports, located near the surface of the aeration tank, to the chimney. When these slot openings are increased in area by adjustment, the recirculation ratio is proportionally increased.

(d) Sludge Wasting

The waste sludge bin is located in the bottom of the settling tank (See Figures 2 and 5) and has a surface area of about 2% of that of the settling tank. Sludge is wasted by means of air lift pumps at solids concentrations of 6,000 to 8,000 ppm.

(e) Plant Adaptability

Rapid Bloc plants have been designed to treat both domestic and industrial wastes and are available in size ranging from the small package plants treating a population equivalent of 100 persons to the large poured concrete forms.

Because of the slope required for the sides of the settling tank, the Rapid Bloc unit is limited in cross section. Thus a large plant may be comprised of several units run in parallel. This fact makes plant expansion a relatively simple operation.

2.2 Oxycontact Process

Degremont have been promoting the combined tank technique of sewage treatment in France for more than 15 years and were the first specialist company in Europe to use this system on an industrial scale for the biological purification of wastewater. In 1950, Degremont built the

first combined plant to be installed in France for the treatment of domestic sewage. This plant, however, employed the basic Infilco unit. On the basis of their experience in the construction and operation of these initial combined units, Degremont developed their Oxycontact plants in 1956.

There are two main types of Oxycontact plants known as Oxycontact T2 and Oxycontact T3; the basic layout of each type is shown in Figures 6 and 7. The difference between the two types involves the sludge recirculation process. In the T2 Oxycontact, the activated sludge is kept in an aerobic state by downward cyclic recirculation in the settling zone. In the T3 Oxycontact, exchange between the aeration and settling zones takes place over the entire depth of the unit, in this way the settled sludge is very evenly oxygenated and the air requirements are further reduced.

2.2.1 Design Description

(a) Aeration

The raw waste enters the aeration tank through a weir or pipe system which ensures even distribution along the entire length of the unit. Air is introduced by means of diffusers located on the bottom of the tank. The air distribution system and the sloping sides of the aeration zone jointly ensure (a) vigorous mixing of the air, activated sludge and raw waste by a double circulatory motion and (b) raising of the water level near the orifices linking the aeration and settling zones. The latter effect makes it possible to transfer up to four or five times the flow entering the plant.

Air is supplied at a rate of 700 cu ft/lb BOD applied through Vibrair diffusers delivering 3 to 4 cfm each at an oxygen transfer efficiency of 4 to 5 percent.

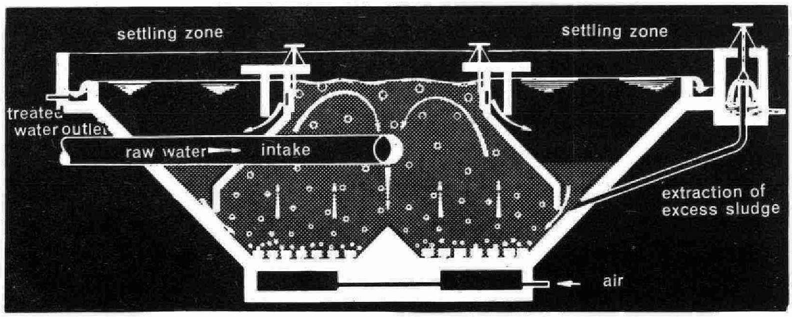


Figure 6 - OXYCONTACT T2

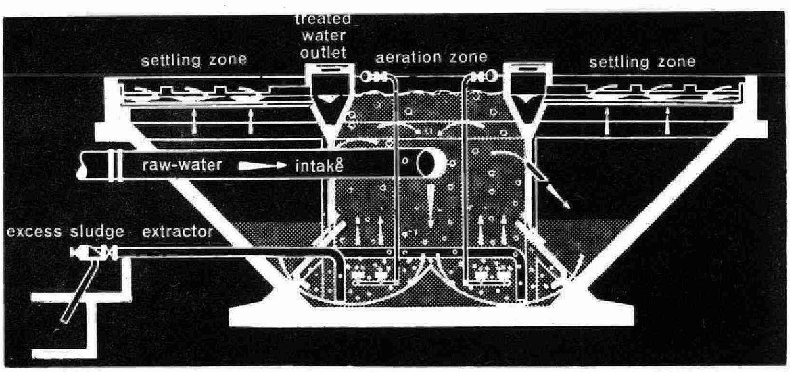


Figure 7 - OXYCONTACT T3

(b) Settling

Settling of the mixed liquor is accomplished in a zone adjacent to the aeration unit. Mixed liquor enters the settling zone through adjustable ports at an elevation just below the level of the mixed liquor in the aeration tank. A baffle, in the T2 Oxycontact, adjacent to the recycling ports, contains a stilling and air-release zone and deflects the mixed liquor downwards. Because of the specially designed exchange ports set at three levels in the T3 Oxycontact the composition, oxygenation and nature of the activated sludge are homogeneous throughout the entire unit and no stilling and air-venting zone is required.

(c) Sludge Return

Sludge return is effected by means of slots, 6 inches in width, running along the bottom of the settling zone. The recycle sludge settles out and collects in the lower portion of the settling zone from where it is then carried, by its own weight and by the downward current of flow, back into the aeration zone. The recirculation rate may be regulated by the adjustable upper recycle ports allowing up to 600% return.

Since the lowest point of the combined unit is in the aeration zone, it is claimed by the manufacturer that the force of gravity alone is sufficient to carry the sludge into the aeration zone. All mechanical scraping of the sludge zone is therefore eliminated as well as the need for pumps for sludge recycling. If the recycling apertures are nearly closed, if the air flow is weak, or if aeration stops due to power failure, the manufacturer claims that the system cannot become clogged.

Excess sludge is drawn off by airlift pumps from the bottom of the settling zone as shown in the accompanying diagrams.

(d) Plant Adaptability

Oxycontact tanks are made of reinforced concrete. The inside walls are either poured on site or prefabricated. If an air distribution floor is fitted, it is made of precast slabs. Plants have been constructed for the treatment of industrial as well as domestic wastes.

The T2 Oxycontact is particularly applicable in the case of high volume loading factors requiring a large volume of air to be injected. It is also often used for the treatment of industrial waste liable to sudden increases in quantity and strength.

The T3 Oxycontact is more suitable for the treatment of domestic sewage; its dimensions being such that the volume of air to the aeration zone does not exceed 66 cu ft/sq ft of horizontal surface. By its design, the T3 Oxycontact is well suited for large plants, where prefabrication on a large scale is possible.

2.3 Aero-Accelator Process

The Aero-Accelator as developed by Infilco Inc. (now a Division of Fuller Company) is a single unit apparatus for treating screened raw sewage by the activated sludge process. In the design of this unit there have been adapted the principles of mixing and solids separation as used in the "Accelator" for water softening and clarification. The process incorporates a mechanical air disperser, which mixes the incoming sewage and air throughout the entire mass of activated sludge present in the unit. This activated sludge occupies about two-thirds to three-fourths of the entire volume of the Aero-Accelator basin.

The use of the Aero-Accelator for the treatment of domestic sewage and industrial wastes is not new. The first plants were modifications of the water treatment equipment and were in operation in 1950. There are now more than two hundred and seventy-five installations treating

domestic sewage and industrial wastes. Experience in the treatment of domestic sewage, phenolic wastes, packing house wastes, paper mill wastes, and others has been obtained.

There are several Infilco installations already in operation in Ontario. Canadian Oil Company Limited (10) installed an Aero-Accelator in 1956 to process a flow of 75 IGM of wastewater with a phenol loading of 150 lbs/day. Regent Refinery (11) installed an Aero-Accelator unit in 1961 to oxidize phenolic compounds in separately gathered phenolic wastewater. There are also two Infilco units treating domestic sewage now in operation in Ontario. These are located at Elliot Lake and at the Bowmanville Boys School.

This system is illustrated in Figure 8. Other modifications of the basic Aero-Accelator are available but will not be discussed in this report.

2.3.1 Design Description

(a) Aeration

The raw or settled waste flows through the intake pipe at the bottom centre (See Figure 8) into the aeration and mixing zone. At this point, air is introduced through a sparger ring and is dispersed by the mechanical aerator. The aerator also acts as a radial type pump which completes mixing of the air and waste and circulates the mixtures within the aeration zone.

The large bubbles of incoming air are broken into very fine bubbles by the shearing action of the rotor. These fine bubbles promote rapid oxygenation and provide a lifting action which conveys the mixed liquor up the inner draft tube where the flow discharges through variable opening gates.

Air requirements are determined from BOD loading, the oxygen required per pound of BOD removed, and the oxygen transfer efficiency of the aeration system. The oxygenation device in the Aero-Accelator unit is a non-clogging

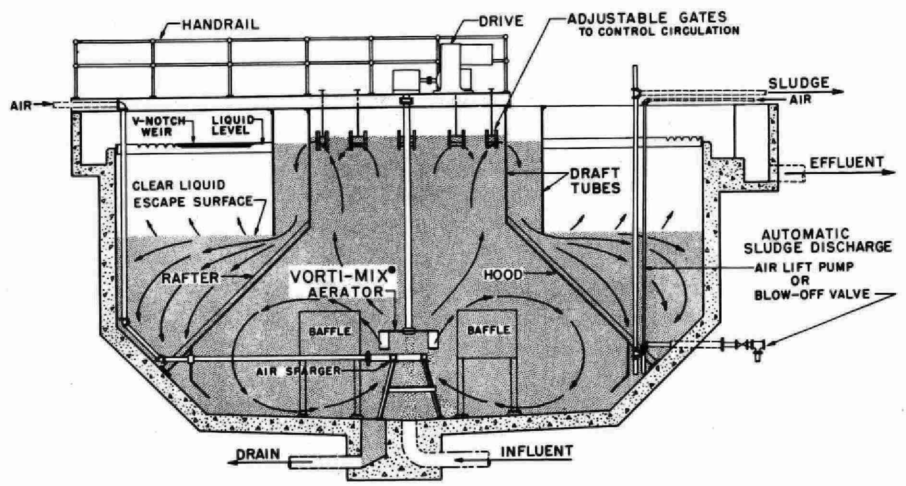


Figure 8 - AERO-ACCELATOR

turbine aerator which either disperses compressed air or entrains atmospheric air. Oxygen absorption efficiencies of 15 to 25% are claimed by the manufacturer to be economically possible. The "Vorti-Mix" aerator commonly used in this process is claimed to provide about 2.5 pounds of oxygen per hour per horsepower applied, including power for air compression.

(b) Settling

The clarification of the mixed liquor takes place in a settling zone, adjacent to the aeration zone. The mixed liquor passes from the aeration tank to the settling tank through adjustable gates and passes down the annular space between draft tubes (See Figure 8) to the clarification zone. The draft tube baffles in the settling zone displace the mixed liquor downward below the surface of the sludge blanket, thus increasing the clarification of the rising liquid. A throughput volume of clarified effluent is displaced from the mixed liquor by the newly entering waste. The effluent rises and flows over the discharge weir at the surface.

(c) Sludge Return

The activated solids separated from the effluent are carried back into the mixing zone beneath the draft tube hood by the recirculating volume of mixed liquor and gravity.

The recirculating flow is normally four or five times the raw sewage flow and is controlled by varying the area of the variable gate openings which control the flow of mixed liquor from the aeration to the settling zone. Solids concentration is controlled by a timer activated blowdown (See Figure 8), or by an airlift pump to an external thickener or digester.

(d) Plant Adaptability

As has already been stated, the Aero-Accelator unit is adaptable to many industrial wastes as well as domestic sewage. The Aero-Accelator unit is available in circular or rectangular form in capacities ranging from 50,000 gpd to over 17 MGD.

3.0 PROCESS DESIGN CRITERIA

The following is a list of design criteria for the High Rate - Combined Tank activated sludge process as adopted by the Quebec Water Board for installations of this process within the Province of Quebec. The criteria were prepared by the Board as a result of a study of this process in France, carried out by Mr. Jolicoeur of the Quebec Water Board in 1963. These criteria are still being followed by the Board although it considers that in the near future some of the criteria may be made less rigid.

(a) Aeration Tank --- maximum loading of 125 lb of BOD/1,000 cu ft of aeration volume with a minimum detention time of 1.75 hrs.

(b) Air Supply --- 1,000 cu ft of air/lb of BOD applied. (Stand by air requirements are identical to those adopted by the OWRC).

(c) Settling Tank --- minimum detention time of 2 hrs at average flow with maximum rise rate of 9 ft/hr, corresponding to a maximum overflow rate of 1,600 gals/sq ft/day at maximum flow.

(d) Sludge Treatment --- since there is a tendency towards the use of an aerobic digester with this process for the treatment of sludge the Board has established a minimum detention time of 10 days for the aerobic digester. This does not preclude the use of other acceptable sludge treatment or handling methods.

4.0 PROCESS OPERATIONAL CHARACTERISTICS

4.1 General Observations

This section presents general observations of the process made at the time of the inspection tour of Quebec installations. A total of eight plants were visited of which five were Rapid Bloc and two were Aero-Accelator installations. A more detailed description of each plant visited has been included in the Appendix of this report.

The various plants visited were operating under a wide range of loading conditions, both hydraulically and organically. Thus, the observation that the process is able to operate effectively over a wide range of operating conditions was possible. Of the plants visited only two were giving poor treatment at the time of the tour and the reasons for their poor treatment could be attributed to poor plant operation techniques rather than to process design.

Observations of treatment results and discussions with the plant operators indicated that seasonal variation had little to no effect on plant operation. This may be attributed to the short detention times which are characteristic of this process.

Microscopic examination of sludge revealed it to be of the same composition as that of the conventional process.

4.2 Treatment Results

Figures 9 and 10 present probability plots of effluent BOD and SS, respectively, for the High Rate - Combined Tank, Extended Aeration and conventional activated sludge processes. As can be seen, the effluent BOD is quite similar in all three cases while the effluent SS is somewhat superior for the High Rate - Combined Tank process than the other two processes.

Table 2 indicates the total number of samples used and the number of plants from which samples were collected in the preparation of these plots.

Table 2

Process	No. of Samples	No. of Plants
Conventional Activated Sludge	1200	57
Extended Aeration	240	28
High Rate - Combined Tank	200	10

Table 3 presents the maximum effluent BOD and SS concentration expected for 15, 50 and 85 percent of the time for each process. Table 4 presents the percentage of time the effluent concentration would be expected to be equal to or less than 15 ppm BOD and SS, respectively.

Table 3

Process	Effluent Concentration (ppm)					
	15%		50%		85%	
	BOD	SS	BOD	SS	BOD	SS
Conventional Activated Sludge	8.4	14.7	17.2	28	32	53
Extended Aeration	5.7	11.5	14.8	29	37	76
High Rate - Combined Tank	6.6	6.4	14.4	13.5	31	28

Table 4

Process	15 ppm Probability Limit *	
	BOD	SS
Conventional Activated Sludge	40	16
Extended Aeration	51	23
High Rate - Combined Tank	52	56

* Percentage probability that the BOD and SS content of the effluent will not exceed 15 ppm.

The preceding tables indicate the effluent from the High Rate - Combined Tank process to be somewhat superior in relation to BOD and SS concentrations than the effluent of the conventional activated sludge and Extended Aeration processes.

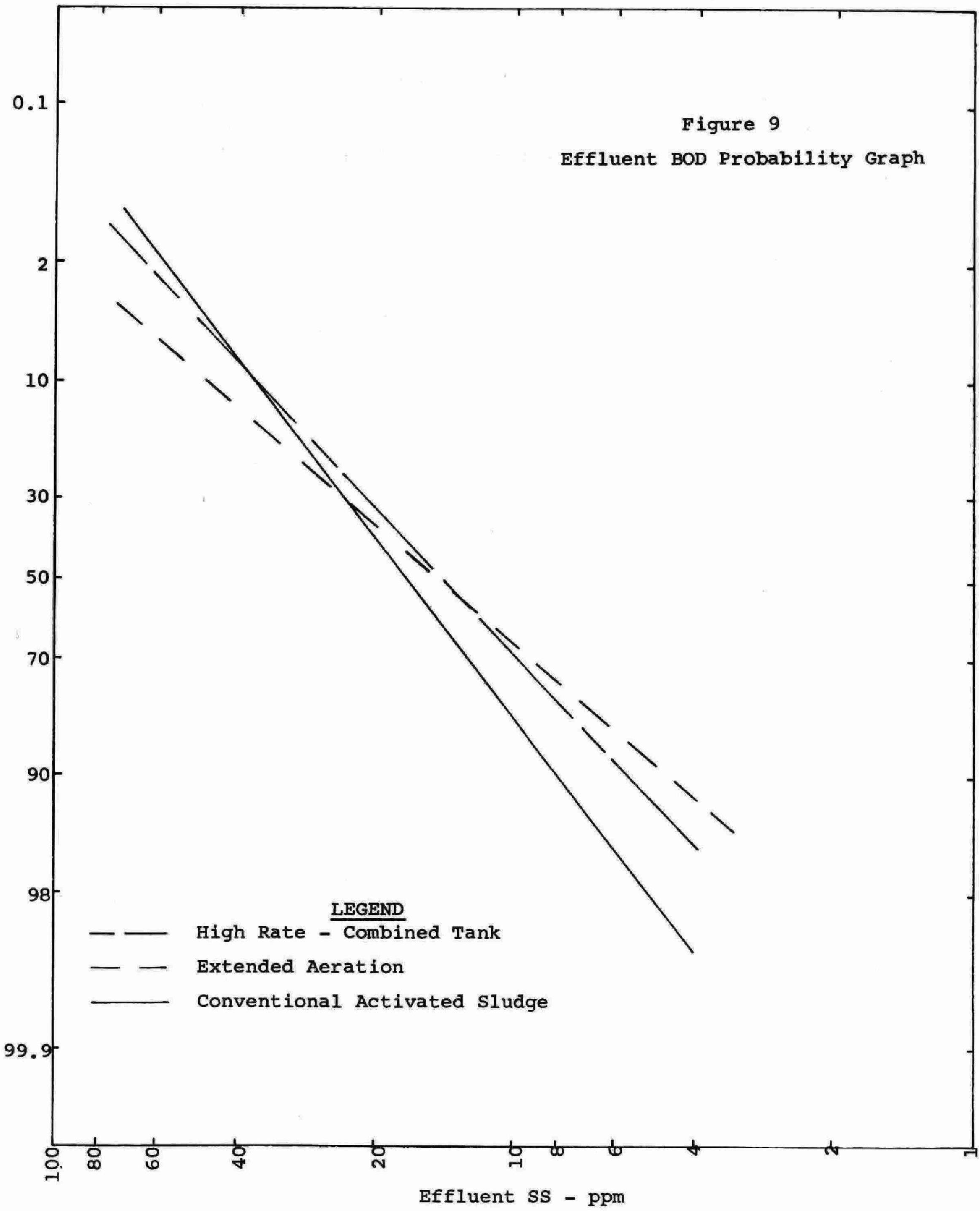


Figure 9
Effluent BOD Probability Graph
0.1
2
10
30
50
70
90
98
99.9
LEGEND
High Rate - Combined Tank
Extended Aeration
Conventional Activated Sludge
100
80
60
40
20
10
8
6
4
2
1
Effluent SS - ppm

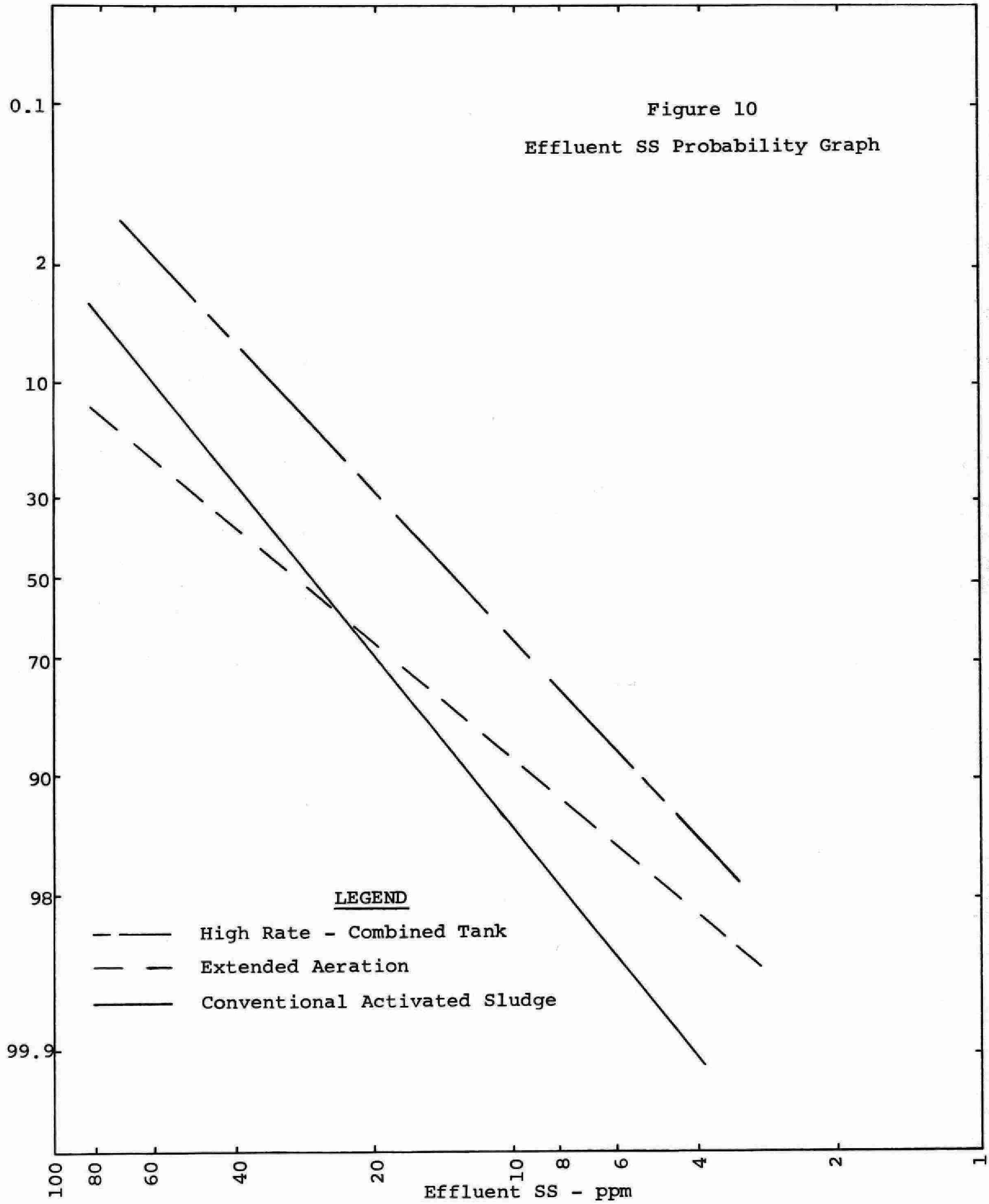


Figure 10
Effluent SS Probability Graph
0.1
2
10
30
50
70
90
98
99.9
LEGEND
High Rate - Combined Tank
Extended Aeration
Conventional Activated Sludge
100
80
60
40
20
10
8
6
4
2
1
Effluent SS - ppm

5.0 PROCESS ECONOMICS

5.1 Capital Cost

Figure 11 presents a capital cost comparison of various sewage treatment processes. It is important to note that land costs have not been included in the capital cost figures and are a substantial percentage of the actual cost of the aerated lagoon, oxidation ditch and waste stabilization pond processes.

As may be seen, the capital cost of the High Rate - Combined Tank plants is considerably less than that of the conventional activated sludge plant. Because of higher allowable loadings and thus smaller tank volumes required, a saving is realized in material, construction and land costs. A 1 MGD plant requires approximately 100' x 100' of land area.

A substantial initial cost saving may also be made due to the fact that a primary clarifier is not essential to plant operation where domestic sewage and certain types of industrial wastes are concerned. The construction of primary settling facilities at a later date provides an economical method of plant expansion provided the necessary allowances are made in initial design.

As may also be seen in Figure 11, the capital cost of the High Rate - Combined Tank plant is highly competitive with that of the lagoon system of treatment, especially if land costs are taken into account.

5.2 Operating Cost

The operating costs of the High Rate - Combined Tank process are estimated to be somewhat below those of the conventional process. The greatest saving here is in wages. A 1 MGD plant requires only eight hours supervision by one man only. Operation of the process is much simpler than the conventional process, requiring less stringent control. Also some power saving in cost/lb BOD removed is realized.

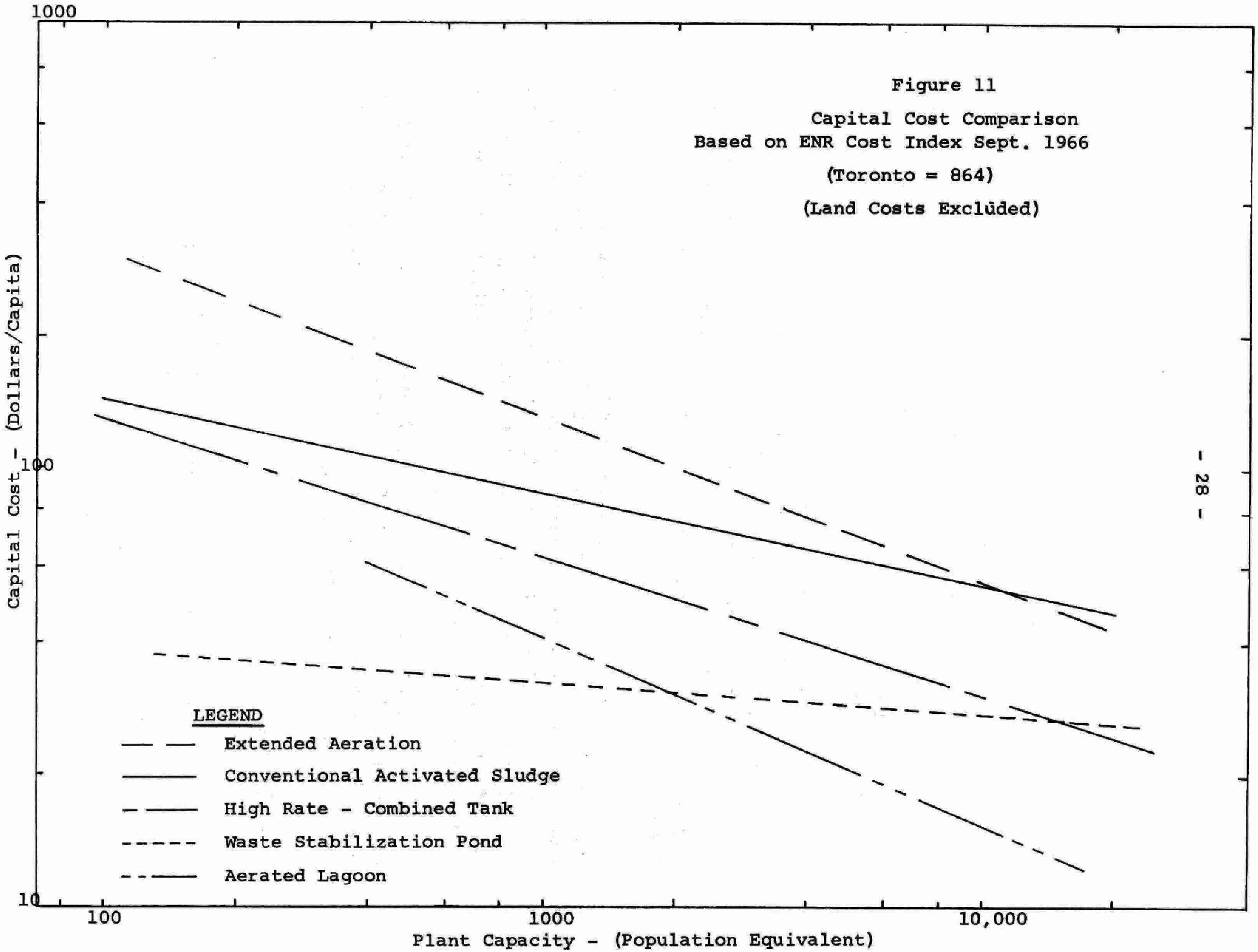


Figure 11

Capital Cost Comparison
Based on ENR Cost Index Sept. 1966
(Toronto = 864)
(Land Costs Excluded)

6.0 CONCLUSIONS

The following conclusions are presented in respect to the foregoing process evaluation study:

1. The High Rate - Combined Tank activated sludge process as studied in this report is a simple secondary treatment process capable of a high degree of treatment, comparable to that of the conventional activated sludge process.

2. The High Rate - Combined Tank process of sewage treatment is capable of operating efficiently over a wide range of operating conditions.

3. Plant operating costs are somewhat less than those of the conventional activated sludge process, particularly in relation to operator wages. These plants are operated with considerably less supervision than is required for the conventional process.

4. Plant capital costs are less than those of the conventional activated sludge process and are competitive with those of aerated lagoons and large waste stabilization pond installations while producing a consistently better effluent.

5. The design criteria adopted by the Quebec Water Board appear to produce a satisfactory effluent under a wide range of operating conditions.

7.0 RECOMMENDATIONS

As a result of the process evaluation presented herein it is recommended that the High Rate - Combined Tank activated sludge process be approved by the Ontario Water Resources Commission for acceptance as a municipal wastewater treatment method within the Province of Ontario.

In the event of approval of this process by the OWRC the following recommendations are made in respect to future installations:

(a) That the choice of proprietary, Rapid Bloc, Aero-Accelator, or Oxycontact be left to the discretion of the municipality and/or consulting engineer.

(b) That initially the Commission adopt the design criteria as established by the Quebec Water Board, with the exception that scum removal facilities be installed in the settling tank when no primary settling facilities are included in initial plant design.

(c) That specific design criteria be established when a detailed study of the process installation is possible.

REFERENCES AND BIBLIOGRAPHY

1. Gould, R. H., Tallmans Island Works Opens for World's Fair, Municipal Sanitation, 10:138 (April, 1939).

2. Setter, L. R., Modified Sewage Aeration, Sewage Works Journal, 15 (1943).

3. Stewart, M. J. (Dr.), Activated Sludge Process Variations, The Complete Spectrum, Parts 1, 11 and 111, Reprinted from April, May, June, 1964 issues of Water and Sewage Works.

4. Boone, R. E., Accelerated Sewage, Water and Sewage Works, May, 1966.

5. Echenfelder, W. W. (Jr.), O'Conner, D. J., Biological Waste Treatment, Pergamon Press, Second edition, 1964.

6. Eidsness, F. A., Some New Developments in Aeration, Sewage and Industrial Wastes, Vol. 23, No. 7, July, 1951.

7. Kalinski, A. A., Pilot Plant Tests on High Rate Biological Oxidation of Sewage, Water and Sewage Works, April, 1950.

8. Kalinski, A. A., Oxygen Absorption Studies Using Mechanical Air Dispersers, Sewage and Industrial Wastes, Vol. 27, No. 5, May, 1955.

9. Klegerman, M. H., High Rate Activated Sludge Treatment Processes, Industrial Water and Wastes, July-August, 1962.

10. Roberts, J., The Collection, Pretreatment and Biological Oxidation of Cresol Bearing Wastewaters from a Catalytic Cracking Unit, Ont. Ind. Wastes Conference Proceedings, 1951.

11. Shaver, R., Wastewater Treatment at Regent's Port Credit Refinery, Ont. Ind. Waste Conference Proceedings, 1963.

APPENDIX

APPENDIX

The following section presents design and operational data for the various plants in Quebec visited by personnel of the OWRC. A brief description of each plant is followed by a summary of its operational data. Although composite sampling techniques were not employed in collecting all samples no attempt will be made to differentiate between grab and composite sampling results. Much of the data was collected by the Quebec Water Board; the remainder by local organizations and consultants.

(a) Lac Etchemine STP - Rapid Bloc

Design Data - 1964

Population: actual - 3,513
design - 4,000

Design Capacity: 400,000 GPD

Rapid Bloc: (2 units of 200,000 gal each)
(i) aeration basin
Volume - 6,210 cu ft (total)
(ii) settling basin
Volume - 5,900 cu ft (total)
Surface - 670 sq ft (total)

Aerobic Digester: (2 units)
Volume - 6,450 cu ft (total)

Chlorine Chamber: Volume - 1,386 sq ft

Operational Data

This plant was overloaded both in organic loading and in flow; overloaded because of a dairy which was not considered in design. Despite these facts, however, the plant appeared to be operating very effectively. The plant was placed into operation in May of 1965, but because of its remoteness from Montreal, the Quebec Water Board had only one set of sample results. However, at the time of this

visit, although heavily overloaded with mixed liquor solids (95% by the 30 min settling test) the plant was still producing a clear effluent. On the basis of infrequent observations, the Board felt that this plant was operating well.

BOD			SS		
Raw (ppm)	Effl. (ppm)	Redn. (%)	Raw (ppm)	Effl. (ppm)	Redn. (%)
200	10	95	360	12	96.5

(b) Laval STP - Aero-Accelator

Population: in summer - 8,000
in winter - 6,500
design - 10,000

Design Capacity: design average - 2 MGD
design maximum - 3 MGD

Primary Settling: 2 units of 1.5 MGD each at 2 hrs retention

Aero-Accelator: (2 units)
volume of aeration - 6,630 cu ft (each)
area of settling - 1,467 sq ft surface (each)

Anaerobic Digester: volume of primary - 20,000 cu ft
volume of holding tank - 10,000 cu ft

Chlorine Chamber: 15 min retention at a flow of 3 MGD

Operational Data

The City of Laval maintains a close control on the operation of this plant and collects samples for analyses at regular intervals. The following table is made up from results obtained both by the Quebec Water Board and by the City of Laval. Flow for the month of October, 1966 averaged 1,279,948 gpd, and is normal between 1.2 and 1.4 MGD.

	BOD			SS		
	Raw (ppm)	Effl. (ppm)	Redn. (%)	Raw (ppm)	Effl. (ppm)	Redn. (%)
Max.	133	18	96	100	8	99
Min.	27	3	81	12	1	63
Avg.	92	8	90	56	5	86

(The above table is a summary of 19 samples collected between March, 1965 and October, 1966)

(c) Papineauville STP - Rapid Bloc

Design Data - 1964

Population: actual - 1,450
design - 2,000

Design Capacity: 160,000 GPD

Rapid Bloc: (2 units of 80,000 gal each)
(i) aeration basin
Volume - 1,900 cu ft (each)
(ii) settling basin
Volume - 1,800 cu ft (each)
Surface - 200 sq ft (each)

Aerobic Digester: Total Volume - 5,000 cu ft

Chlorination Chamber: Volume - 1,000 cu ft

Operational Data

Only one unit of this plant was being operated at the time of inspection, thus, only one-half of the installed capacity was being used to treat the actual flow. The actual flow averaged 69,000 gpd during October, 1965. At the time of this inspection the daily flow was 130,000 gpd; the raw sewage being characteristically high in grit and grease content.

	BOD			SS		
	Raw (ppm)	Effl. (ppm)	Redn. (%)	Raw (ppm)	Effl. (ppm)	Redn. (%)
Max.	280	131	97	264	43	99
Min.	48	9	50	40	0	50
Avg.	165	24	85.5	120	29	76

(The above table is a summary of 22 samples taken between July, 1965 and November, 1966)

(d) Sainte-Agathe-Sud STP - Rapid Bloc

Design Data - 1965

Population: actual - permanent 1,800
- seasonal 700
design (1980) 4,000

Design Capacity: 320,000 GPD

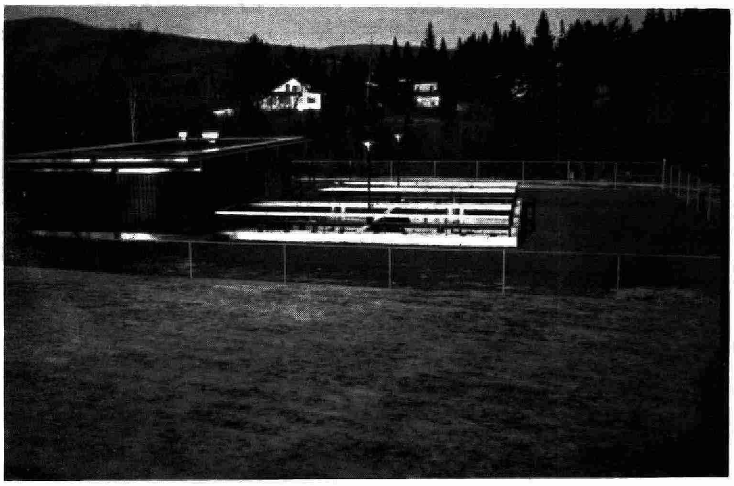
Rapid Bloc: (4 units of 80,000 gal each)
(i) aeration basin
Volume - 1,900 cu ft (each)
(ii) settling basin
Volume - 1,600 cu ft (each)
Surface - 200 sq ft (each)

Aerobic Digester: 2 units of 5,100 cu ft (each)

Chlorine Chamber: Volume - 2,200 cu ft

Operational Data

Only two units of this plant were being operated at the time of this inspection tour. The total actual flow averaged 156,800 gpd during the period August to October, 1965.



ST. AGATHE RAPID BLOC PLANT

	BOD			SS		
	Raw (ppm)	Effl. (ppm)	Redn. (%)	Raw (ppm)	Effl. (ppm)	Redn. (%)
Max.	71	37	94	201	50	98
Min.	22	4	32	8	1	40
Avg.	46	12	76	61	19	71

(The above table is a summary of 17 samples taken between July, 1965 and November, 1966)

(e) Sainte-Eustache STP - Aero-Accelator

Design Data - 1962

Population: actual - 7,200
design - 10,000

Design Capacity: design average - 1.2 MGD
design maximum - 3.6 MGD

Primary settling: 2 units of 20,250 cu ft (each)

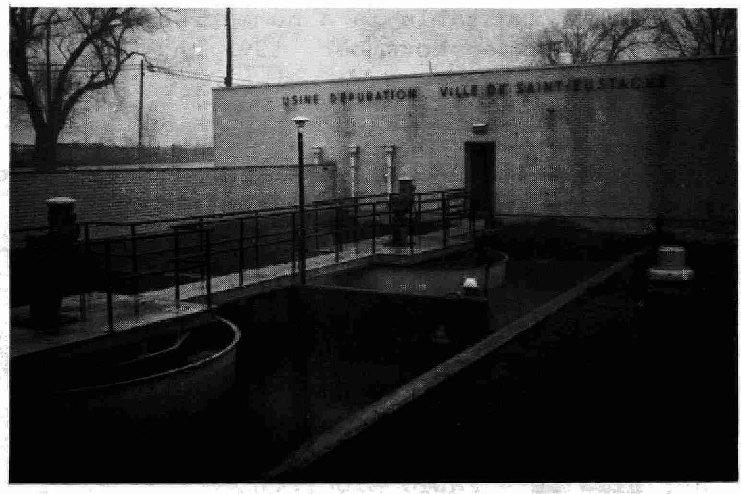
Aero-Accelator: (2 units)
volume of aeration - 3,600 cu ft (each)
volume of settling - 1,140 cu ft (each)

Sludge Filter: 1 Kombline Sanderson filter of 100 sq ft

Chlorine Chamber: 15 min retention at maximum flow

Operational Data

At the time of the visit to this plant, it was operating very poorly because of high flows. The actual dry weather flow normally received was 350,000 gpd and all equipment was set for this flow rate. When these flows were exceeded, no attempt was made to adjust air rates and thus the plant became temporarily upset until the high flow receded back to normal.



ST. EUSTACHE AERO-ACCELATOR UNIT

The operator indicated that approximately 6" of sludge settled out on the bottom of the aeration tank and at high flows, short circuiting of raw sewage to the settling tanks occurred. These phenomena could not be confirmed at the time of the visit. However, treatment at this time was very poor apparently due to operational procedures.

The following table is a summary of 29 sets of samples collected between November, 1963 and October, 1966.

	BOD			SS		
	Raw (ppm)	Effl. (ppm)	Redn. (%)	Raw (ppm)	Effl. (ppm)	Redn. (%)
Max.	264	68	97	433	53	96
Min.	32	5	33	27	1	26
Avg.	90	16	83	86	17	77

(f) St. Hilaire - Rapid Bloc

This is a Rapid Bloc package plant designed to treat the waste from a small boarding school of 100 persons. It has a design capacity of 10,000 gpd.

There are only three incomplete sets of results of the plants operation and they do not indicate very favourable results.

The drawback of a small package plant of this scale is in the operation of the plant. It is difficult to get an operator to give it the small amount of attention it requires.

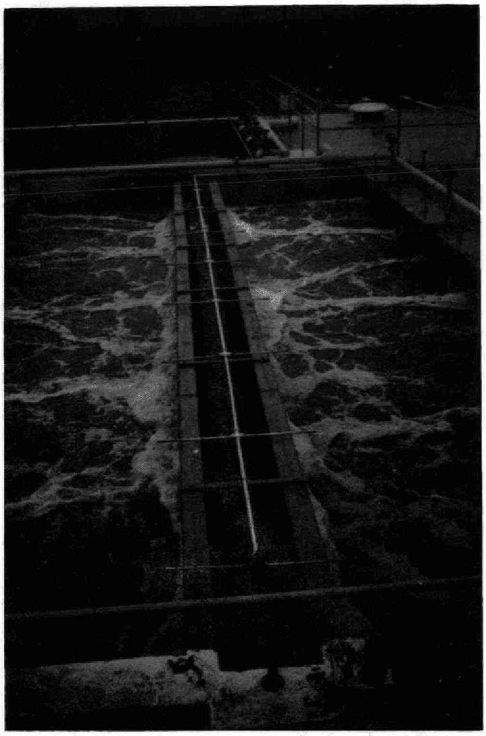
At the time of the visit to the plant it was operating very poorly because of several reasons, all of which appeared to be the fault of the operator.

A plant of this scale should work successfully with a minimum of surveillance but it cannot be neglected.

ST. HILAIRE RAPID BLOC PACKAGE PLANT

(g) St. Remie STP - Oxycontact

At present, there is only one Oxycontact unit in operation in Canada. This is the St. Remie plant which was placed into operation in July of 1966. At the time of the visit to the St. Remie plant it appeared to be operating very effectively and the Quebec Water Board was pleased with its performance.



ST. REMIE PLANT OXYCONTACT
AERATION UNIT

ST. REMIE PLANT OXYCONTACT
SETTLING UNIT

PERSONNEL

The following personnel of the Ontario Water Resources Commission assisted in the collection of data for, and in the preparation of this report:

Mr. A. R. Townshend, Supervisor, Design Approvals Branch, Division of Sanitary Engineering.

Mr. D. M. Decaire, Field Projects Branch, Division of Research.

969360000009114